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Remote Sensing towards Water Quality Study in Malacca River Case Study : A Review Perspective

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ABSTRACT

Water is among the natural resources that needed by living organisms such as human. Rapid development through human activities leading to the water pollution existed in river, for example Malacca River. Therefore, a literature review has been conducted to identify the effectiveness of using remote sensing towards water quality in Malacca River. Various research studies conducted by scientists and researchers stated that data from the satellite like Landsat, IKONOS, SPOT, IRS, CZCS, and SeaWiFS may be applied in assessing water quality parameters including suspended matter, turbidity, phytoplankton, and dissolved organic matter. The measurement for water quality parameters can be carried out through in-situ measurement, as experimental examination may be done through on-site studies and inside laboratories. Water quality assessment is extremely needed to strengthen the result produced through analysis of remote sensing data to determine the impacts and factors that contributed to the river pollution. As a result, remote sensing data from Landsat, IKONOS, Quickbird and SPOT may be applied to determine water quality parameters such as suspended matter, phytoplankton, turbidity, dissolved organic matter, and other parameters in the Malacca River. As conclusion, remote sensing has become a tool in monitoring and solving water quality issues, serving as a basis for management activities and planning activities in terms of river water quality.

Keywords: Rapid development, effectiveness, assessment, monitoring, management, planning

I. INTRODUCTION

Natural water resources are God's creation, and are an indispensable element to most of creatures. For example, the importance of water to human beings is to regulate body temperature, helps to carry nutrients and oxygen to cells, moisten oxygen for breathing, help to convert food to energy, protect and act as cushions towards vital organs, remove waste, act as cushion for the joints between bones, and help the body to absorb nutrients. Therefore, water resources have the ability to maintain the quality of human life through the balance of metabolism in the body for growth from the childhood to adulthood and until the old ages. However, intake of water resources depends on the quality of water supplied. Water should be totally clean, clear, and free from any harmful bacteria threat. According to the percentage of world fresh water statistics, only 2.5 percent of freshwater (where 1.2 percent can be found through the water surface and remaining percentage can be obtained through groundwater or in the form of ice) may be supplied directly to living beings [27]. In other words, the supply of freshwater resources remains minimal in terms of helping living beings to continue to survive on the earth's surface.

The earth has been developed quickly in terms of human pursuit of development and modernization without any limitation and barriers, helping in reducing any difficulties and providing a variety of facilities to humans. This includes the development of the airplane, which has improved the accessibility from destination to destination and shortened travel time. This also includes the existence of smartphones helping to strengthen the relationship between peoples separated by the vast expanse of the Pacific Ocean. On the other hand,

modernization not only brings benefits but also contributes a number of detriments to society. These issues exist due to the greedy attitude and selfishness of human that forget their responsibility towards the natural environment which cause pollution to occur, such as river water pollution. Referring to the Environmental National Geographic, developing countries have contributed about 70 percent of water pollution by industrial waste into the water of rivers, causing the percentage of water supply to decline. In other words, the 99 million pounds of fertilizer and chemicals used every year produce a very high percentage of water pollution, and this situation is harmful to living beings on the earth [8]. A research study that carried out by Cornell University (2007) has stated that about 40 percent of deaths in worldwide are caused by water, air, and soil pollution, as these problems can happen due to environmental degradation, increasing world population, and rapid development in urban areas [4]. Therefore, determination towards water quality in the river and determine the factor that contribute to river pollution is requires categorization in order to reduce the percentage of pollution from continuously increasing.

In Malaysia, there are several issues and problems that need to be noted especially development in river basins, such as environmental impacts (high siltation in river and lakes, point and non-point source pollution, and so on) and social impacts (industrialization increase, population growth increase, improper land use increase, and so on). These activities allow soil erosion to the water, increase matter mixture, turbidity, organic matter and river sedimentation problem. As general, the water characteristics can be categorized into physical, chemical, and biological factors. However, there are specific parameters used to determine the water quality studies, namely Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Ammoniac Nitrogen (NH3-N), Suspended Solid (SS), and pH. The six parameters are formulated as a general measurement and are often used in assessing water quality, also known as the Water Quality Index (WQI). According to data from the Department of Environment Malaysia (2012), out of 473 rivers monitored, 278 (59%) were found to be clean, 161 (34%) were slightly polluted, and 34 (7%) were polluted [6]. Stations located upstream are generally slightly polluted due to physical parameters, while downstream were slightly polluted or polluted due to chemical and biological parameters. The polluted rivers are mostly located in development and industrial areas such as Sungai Pinang, Sungai Juru, Sungai Merlimau, Sungai Danga, Sungai Segget, Kawasan Pasir Gudang, and Sungai Tebrau [7]. Therefore, technology such as remote sensing is a very powerful and useful tool in assessing and monitoring water quality.

II. METHODS AND MATERIAL

Malacca, also known as the historical city, received recognition from UNESCO on 07 July 2008 [24] [2] as a world heritage site, which has become the starting point of the tourism industry based on the historical city (e.g. Fort A Famosa, St. John's Fort, Christ Church, etc.) and social-cultural heritage (e.g. Baba and Nyonya cultural features, Portuguese cultural, Malacca Sultanate Palace Museum, etc.) [25] [15]. According to the geographical coordinates of Malacca state, it is located at latitude of 2°11'39.53"N and longitude of 102°14'56.58"E [17], which covers an area of 1658 that divided into three districts, namely Melaka Tengah, Alor Gajah, and Jasin [17]. Melaka Tengah has become the main city and capital of Malacca State. There are several transport facilities accessible to Malacca State by road, rail, and airplanes [16]. On the other hand, the statistics for the number of population in the state of Malacca was 830 900. Most of the local residents are Malay with total of 523 800, followed by Chinese with 210 100, Indian with 49 400, and others with 48 500 [17]. Therefore, this situation shows that rapid development has taken place in the state of Malacca, which has not only attracted the attention of all levels of society in providing jobs, but also provided an opportunity to engage in business in the tourism industry in Malacca State.

The rapid development in the state of Malacca has contributed various advantages and disadvantages towards the local citizens. For examples, the advantages that can be seen are through providing job opportunities, business opportunities, investment opportunities, and so on. However, the development could also bring disadvantages to Malacca State, where it will cause river water pollution to occur [18], as this situation will lead to the spreading of infectious diseases, killing aquatic animals, damage the landscape and produce bad odor sensed, and disrupt the relationship between human with the environment such as through recreational activities. Until now, the river pollution is still currently occurring

and this situation does not show any change to positive impacts [12]. This may be proven through the research studies conducted by Hua (2014), as the majority of respondents agreed that the pollution in the Malacca River still occurs due to the construction of industries, the construction of buildings, the settlements and so on, as carried out adjacent to the Malacca River [11]. Hence, this literature review study has been conducted to determine the effectiveness of remote sensing as a modern technology tool that can help in planning water resources in Malacca River.

A. Sampling Area

The sampling area that chosen for this study is Malacca State (figure 3), where a small scope is concentrate along the river in Malacca (figure 4). The vastness for Malacca State is 1650 km2, where it can be divided into three districts, namely Alor Gajah (660 km2), Jasin (676.07 km2), and Melaka Tengah (313.93 km2) (Melaka State Government Official Portal). Referring to the total population by districts, Melaka Tengah has the highest population with the value of 510 257 peoples, followed by Alor Gajah district with a value of 189 796 peoples, and the last district is Jasin with the value of 142 447 peoples [16]. Meanwhile, the position of Malacca River shows the flow of water is flowing from upstream (part of Alor Gajah) to downstream (part of Melaka Tengah) before the water is discharged into the Straits of Malacca. There are various tributaries that flow from various directions before entering the main river. The existence of these tributaries will result in a river basin and watershed, which is important to act as a supply of clean water to the human and ecosystem. The existence of Malacca River is due to the water that flows from small streams into the main river, which has a length of 42 km2 [21]. Hence, the Malacca River is relevant and appropriate to serve as a sample area in this literature study.

Figure 3. Malacca State according to the districts
Source: Malacca Town and Country Planning Department, 2012

Figure 4. Malacca River across the districts.
Source: Malacca Town and Country Planning Department, 2012.

B. *Remote Sensing*

Remote sensing is a tool that has the ability to observe information about the earth's surface and water surfaces by using satellite technology and interpreting them into images using electromagnetic spectrum through electromagnetic radiation (figure 5). In Malaysia, the satellite technology is controlled by the government department known as Malaysian Remote Sensing Agency (MRSA), which controls several satellites such as Landsat-1 MSS, Landsat-5 TM, Ikonos-2, GeoEye-1, and SPOT-1 to SPOT-6. Each satellite has a specific function, where Landsat obtaining information on agricultural and forestry resources, geology and mineral resources, hydrology and water resources, geography, cartography, environmental pollution, oceanography and marine resources, and meteorological phenomena. SPOT satellites are designed to improve the knowledge and management of the Earth by exploring Earth's resources, detecting and forecasting phenomena involving climatology and oceanography, and monitoring human

activities and natural phenomena. Ikonos satellites have the ability to extract vector features and geographic features in 3D such as buildings, roads, manmade structures and other terrain feature, and also include mapping for oil and gas exploration, mining, engineering and construction, environmental, urban planning, agriculture, and forestry. GeoEye helps the user in mapping, change detection and image analysis [22]. Therefore, remote sensing technology is believed to be able to solve the problems mainly involved with environmental monitoring such as river water pollution and determine the development in urban planning in Malacca State.

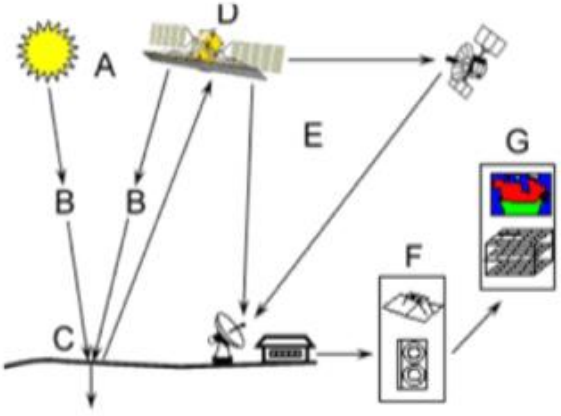

Figure 5. The absorption process by remote sensing. Source:http://margaux.ipt.univparis8.fr/vgodard/enseigne/tele d2/memotele/imemtele/tfm12fi1.gif

III. RESULT AND DISCUSSION

A. Application of Remote Sensing towards Water Quality Study

Water can be determined in two methods, namely internal characteristics and external characteristics. Internal characteristics refer to water quality involving chemical, physical, and biological characteristics. Meanwhile, external characteristics can be defined as the water surface that interacts with the outer elements to result in any changes in water quality. The chemical, physical, and biological characteristics of water bodies are important in a water quality study because it can help in determine and identifying the source of any possible pollution or contamination which might cause degradation of water quality. The water quality indicators can be divided into four main types, per Usali and Ismail (2010) [26]:

(1) Biological : bacteria (total coliform, E coli, fecal coliform) and algae
(2) Physical : temperature, turbidity & clarity, color, salinity, suspended solid, dissolved solids.
(3) Chemical : pH, dissolved oxygen, biological oxygen demand, chemical oxygen demand, nutrient (nitrogen and phosphorus), organic and inorganic compounds.
(4) Aesthetic : odors, taints, color, and floating matter.

Hence, a water quality study can be determined through the Water Quality Index (WQI), where this experimental are need to carry out through in-situ measurement (experimental can be done on-site studies and inside laboratory). This has become an important method for monitoring water quality parameter with the purposes to improve the river water quality in becoming a clean condition like reducing the higher percentage to lower percentage of pollution class; and help to restore, conserve, maintain and sustain water quality in a clean status. However, external characteristics also need to play a role together with internal characteristics so that the objective can be achieved, for example remote sensing. Remote sensing has become a usefulness tool in monitoring water quality [19] [23] [5]. Research done by Ritchie et al. (1976) stated that remote sensing has the ability to monitor water quality study [20]. They developed a general formulation equation towards suspended sediment as follows:

$$Y = A + BX \text{ or } Y = AB^X$$

Where:
Y is remote sensing measurement (radiance, reflectance, energy);
X is water quality parameter (suspended sediment, turbidity);
A and B determine the spectral reflectance value and between in situ water quality parameters.

The spectral reflectance will provide information about band or wavelengths for water quality parameter. Since

that, the formula starts to be applied by researcher to estimate the water quality, and the equation is being used until today.

B. Water Quality Parameter versus Remote Sensing

Remote sensing can used to determine water quality parameter through suspended matter, phytoplankton, turbidity, and dissolved organic matter. Suspended matter consists of organic and inorganic matter, which involve with heavy metal and micro-pollutants. Both pollutants are affecting the surface water. When examined through remote sensing, the suspended pollutants will result the radiance in visible and near infrared ranged of electromagnetic spectrum [19]. So, when carrying out a laboratory experiment, the results show that the water is affected by sediments type, texture, color, sensor view and sun angles, as well as water depth [19]. Among of remote sensing data that suitable to be applied is Landsat, SPOT, Indian Remote Sensing (IRS), Coastal Zone Color Scanner (CZCS) and Sea-viewing Wide Field of View Sensor (SeaWiFS) [26]. Continued by the phytoplankton, this may be defined as the concentration of chlorophyll contain in algal plankton cell that exist in the water. According to Schalles et al. (1998), since chlorophyll is a photosynthetic agent that can contribute to the change of water color, so remote sensing can be used for mapping the chlorophyll A, which becomes a key for assessing the water quality [23]. Conducting a research study especially at the lakes, rivers or reservoirs will have a higher percentage of chlorophyll A; however, the presence of pollutants will impact the color and affect the routine extraction of chlorophyll A from the original which can be detected in remote sensing. Hence, only certain data like Landsat, SPOT, SeaWiFS and CZCS may be used to map the chlorophyll of oceans, estuaries, and freshwater [26].

Thirdly, turbidity can be expressed as the cloudiness or haziness of fluid due to the individual particles that invisible to naked eye, which caused light to be scattered and absorbed rather than transmitted in straight lines in remotely sensed data. In other words, turbidity can be considered as against the clarity. Turbidity mainly caused by the present of suspended matter, which is used to calculate fluvial suspended sediment concentration [28]. The Lathrop and Lillesand (1986) research study states that normally turbidity pollution will result in red reflectance [13]. This condition is more precisely in using data from the IKONOS which have high resolution for mapping the turbidity [9] or using Landsat 7 ETM+ Band 3 (red portion of electromagnetic spectrum) and Band 4 (near-infrared portion of electromagnetic spectrum) data to predict turbidity concentration [14]. Lastly, this may be related to dissolved organic matter, which is normally affecting the water color by soluble organic substances (that can pass 0.45µm filter) which are also referred to as Colored Dissolved Organic Matter (CDOM). In other words, CDOM is the fraction of dissolved organic substances and it is exist in water-soluble, biogenic, heterogeneous organic substances that are yellow to brown in color [1]. Basically, dissolved organic matter affects the volume of reflectance and volume spectrum, especially at the shorter wavelengths [3], and CDOM absorbs light in both ultraviolet and visible range (below 500µm) [26]. A research study done by Strombeck (2001) stated that the quantity of red light can be absorbed by CDOM at higher concentration [29]. At the same time, CDOM have an ability to absorb the UV spectrum portion which become a protection to the phytoplankton from the destruction of UVB radiation [10]. However, this will result in affecting the amount and quality of photosynthesis to phytoplankton, due to the excessive absorption of UVB by CDOM at higher level.

C. An Overview of Remote sensing towards Water Quality Study in Malacca River

As a general view, the majority of local residents are settled down nearer to the Malacca River. This situation shows that the land use by local residents can be divided into three main parts, namely upstream, middle stream, and downstream. Basically, the land use for upstream area is involved with farming activities, livestock activities, and settlements activities. The middle stream area is involved with industrial activities, manufacturing activities, and settlement activities. Lastly, the downstream area is comprised of commercial activities, domestic activities, and settlement activities. These activities can be generally observed through the map in figure 6.

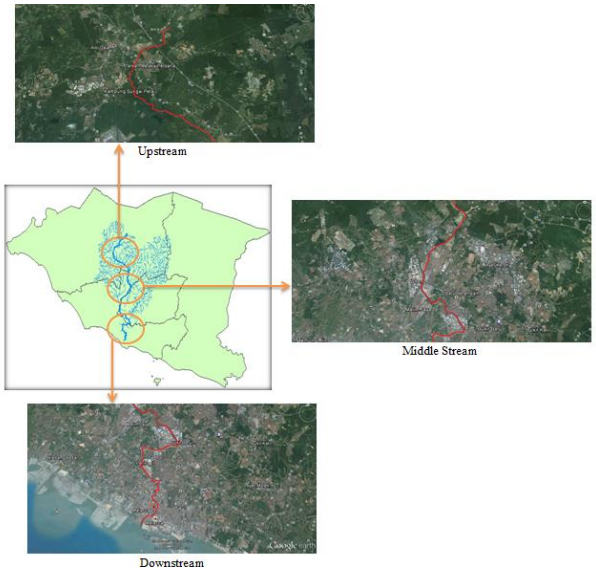

Figure 6. Human activities along the Malacca River.
Source: Malacca Town and Country Planning Department (2012) and Google Earth.

Since there are various activities carried out in Malacca State, the remote sensing data that can be apply are Landsat, IKONOS, Quickbird, and SPOT, which depend on the data that can be supplied by the Malaysian Remote Sensing Agency (MRSA). So, this data from different satellites can be used to determine water quality parameters such as suspended matter, phytoplankton, turbidity, dissolved organic matter, and other parameters. These factors depend on the ability and suitability between remote sensing data and water quality parameter.

IV. CONCLUSION

Water is a vital natural resource to carry out various activities such as agricultural and livestock activities, industrial and manufacturing activities, and commercial and domestic activities. However, rapid development has led to increasingly severe use, causing the quality of water to decrease and increasing percentage of river pollution. Hence, a monitoring program is indispensable to reduce river pollution before conduct any management and planning activities for the future. Therefore, the monitoring program will require remote sensing as a tool of modern technology that has ability to assess the impact and factors which contributed to the river pollution. Remote sensing data results will be more precise when carrying out a water quality assessment in the laboratory. So, remote sensing and water quality studies depend on each other in solving the problem of river pollution. Previous studies using remote sensing techniques towards water quality parameter are more helpful for to scientists, researchers, academicians, lecturers, and students, especially in mapping or modeling using data from satellite such as Landsat, IKONOS, SPOT, CZCS, and etc. Last but not least, remote sensing will become a tool in solving the water quality issues for the past, present, and future.

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